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by

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REAR ADMIRAL EDWARD N. PARKER, USN
DEFENSE ATOMIC SUPPORT AGENCY
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Radioactive Fallout From Nuclear Explosions

1. INTRODUCTION

Three years ago Dr. Frank Shelton and Major General Luedecke appeared before this committee to discuss Fallout from Nuclear Weapons. Since that time there have been a number of forward strides made in our knowledge of the subject. In addition, there has been considerable public discussion of fallout and its possible effects either in some future war or as a result of past nuclear tests.

World-wide fallout from these tests has been the subject of considerable concern, substantial differences of opinion and much controversy.

To a degree this controversy has existed because we were dealing with what appeared to be a new phenomenon. There has been widespread ignorance of the facts concerning radioactivity not only among laymen but also among the "experts." This is not surprising when one considers the broad spectrum of disciplines which are involved in the topic of fallout and its effects. Nuclear physics, meteorology, soil science, plant biology, medicine, genetics, and political science all have important things to say on this subject and most studies have involved groups of people with the normal differences of opinion or of emphasis expected in any group.

A great deal of credit must be given to the Congress itself in helping to dispel the aura of mystery which has beclouded the fallout situation. In 1957 and again in 1959 the Joint Committee on Atomic Energy conducted quite comprehensive studies of all aspects of fallout from nuclear weapons tests. In addition, that committee conducted a hearing on what would happen to this country in a large scale nuclear war. Hearings on radiation standards are to be held this coming May.

Besides the Congress, other governmental agencies have published extensive information on fallout. The United Nations has also entered the field of gathering and disseminating such information.

Today, in a short period of time, I will review the essential features of the fallout problem and attempt to bring into perspective some of the controversial issues. I would like to indicate at the outset that in some areas most of the experts agree, but in others there are still wide divergences of opinion. Where disagreement exists, I will endeavor to point it out. I have tried to keep my statement as nontechnical as possible; however, the very nature of the subject forces us to use certain technical terms which are defined in an attached list. We are prepared to go as far as you may desire during the question period which follows.

At the outset I would like to indicate that my organization, the Defense Atomic Support Agency, has in the past been responsible for conducting nuclear weapons tests in concert with the Atomic Energy Commission. The three military services have participated fully in these tests since they are the ultimate users of these weapons and to a large measure specify the military requirements for them. Obviously, either to use efficiently or to defend against nuclear weapons, we must know the effects produced by such explosions. Consequently, we have spent a great deal of time, effort, and money in instrumenting tests to determine the significant effects. We have a continuing research program to correleate and evaluate the data we have gained and to gather these facts together into a form which will be of greatest use to the government. Naturally fallout with its far-reaching casualty producing properties has had a great deal of attention.

Besides the instrumentation in the immediate vicinity of testing, much effort has been expended to determine the amounts of radioactivity which is spread to great distances. At the present time, collections are being made by the Public Health Service, the U. S. Weather Bureau, the Department of Agriculture, the Atomic Energy Commission, and at least four Department of Defense agencies. Each of these sampling programs has provided valuable information in disclosing the overall fallout mechanisms. Continued monitoring of this nature will refine even further our already fairly accurate picture. In addition to the Federal agencies, state, and private organizations, such as Minnesota Department of Health, and the Consumers Union are in the sampling business.

II. PHYSICS OF FALLOUT PRODUCTION

When a nuclear detonation of any type occurs there is a concurrent production of radioactive particles. These can vary in type and number depending upon the nature of the device and its surroundings.

There are two basic types of reactions which occur in a nuclear explosion. The first is fission, where heavy elements are broken up into lighter elements with a consequent release of energy. The second is fusion, where very light elements are coalesced thereby producing a similar release of energy.

Fission products are almost without exception radioactive, and they constitute the major portion of the radioactivity in fallout. Some of the products of fusion are radioactive but they differ from fission products in several ways. The most important difference is that they do not fall down in the immediate vicinity of an explosion and thus do not ~~contribute~~ contribute markedly to the high levels of radioactivity which characterize local fallout. This fact has generated the use of the somewhat misleading "clean bomb" concept. In actuality the fusion reaction can produce abundant quantities of free neutrons. These neutrons can induce activities in the material surrounding the bomb. The activated materials will vary considerably in type or quantity depending upon the make-up of the bomb case and accessories and the make-up of the soil or water on which the bomb is burst. Neutrons striking nitrogen in the air will produce carbon-14.

To date, man-made carbon-14 production has increased the natural cosmic ray-produced reservoir by about 1%. The activity from carbon-14 is negligible when compared to that of fission products but may have important genetic effects. Even soil and bomb case induced activities are small when compared to that of fission products, and, except in the case of high yield, predominantly fusion weapons, are not considered a major factor in the fallout problem.

About 400 different varieties of fission products are produced. The quantity of each type made will be determined by the yield of the weapon, type of materials used, and their arrangement in the weapon. The highly penetrating gamma radiation emitted by the fission products during the first minute along with the excess neutrons are referred to as the prompt radiation. The fission products thrown up by the explosion eventually fall back to the ground in various ways. The residual radiation from these products constitute the fallout hazard.

To give you some grasp of the amount of radioactivity which is produced, it can be shown that one minute after the firing of a 1 kiloton explosion, the two ounces of fission products produced have an activity equal to that of 100,000 tons of radium. However, unlike radium, the intensity of this radiation weakens as time progresses so that for every sevenfold increase in time after one minute, the radiation level is reduced tenfold. By the end of three months our 2 ounces of fission products would have an activity equal to that of 250 pounds of radium while the activity of the 100,000 tons of radium would have been reduced hardly at all. The relative importance of any one isotope produced in a nuclear explosion depends upon many factors. Some of these factors are abundance and manner of production, half-life, mode of decay or loss of radioactivity, and chemical nature. We will discuss later some of the specific isotopes which are considered of long range biological significence.

III. INITIAL SCATTERING OF FALLOUT PARTICLES

There are a number of factors which influence the way in which the various elements comprising the debris from a nuclear detonation are scattered about. The major factors are size of weapons, height of burst, type of surface over which it is burst, and type of atmosphere.

Let us discuss for a moment the structure of the atmosphere. The lower portion, known as the troposphere, can best be described as the weather making part of the atmosphere. Here we find relatively moist air heated by the warmed surface of the earth, a situation which leads to the production of clouds, turbulence, and rainfall. The stratosphere sits on top of the troposphere and exhibits little cloudiness or turbulence. The boundary between these areas lies at about 55,000 feet in the tropics and slopes off to between 25 and 35,000 feet in the temperate and arctic regions. In the middle latitudes there is a rather sharp discontinuity in this boundary, or tropopause as it is called. As we shall see later, it is this break in the tropopause which appears to provide the major avenue for stratospheric fallout to enter the troposphere. The arctic stratosphere exhibits a greater degree of turbulence than the tropical stratosphere, especially in the wintertime.

If a weapon is fired sufficiently high above the ground, there will be essentially no local fallout. This is the situation which prevailed at Hiroshima and Nagasaki. Casualties in those cities were produced by the blast, thermal, and prompt radiation effects of the bombs and their secondary effects, such as flying debris and fires.

As the height of burst is lowered toward the surface of the earth, more and more materials will be vaporized and sucked up from the ground into the fireball. This material will condense into relatively large particles containing fission products and will promote their early removal from the cloud. This is the local fallout which will give doses which can easily be lethal in a short period of time to unprotected people as far as several hundred miles away for sufficiently large weapons. The minimum height above the ground at which the weapon can be exploded to produce no local fallout depends upon the size of the weapons and can be calculated with a fair degree of accuracy. Since larger weapons produce larger fireballs, it is apparent that larger weapons must be burst at higher altitudes to prevent local fallout.

The material not deposited locally will be carried to great distances by the winds. Eventually this material will be incorporated into rainfall and will reach the ground. Sufficiently large weapons can put a part or all of their radioactivity into the stratosphere. A one megaton land surface burst in the tropics would place less than one quarter of its radioactivity in the stratosphere since the soil sucked up into the fireball would tend to reduce the height to which the cloud could rise and would tend to promote the early fallout of the fission products. This same weapon burst over water or in the air would place more than half of its radioactivity in the stratosphere. An air burst of this weapon in the northern latitudes would place practically all of its radioactivity in the stratosphere.

To date approximately 92 megatons of fission products have been manufactured by all nations during weapons test. About 50 megatons of this material has been injected into the stratosphere, 25 from Pacific tests and 25 from Siberian tests. Before we discuss the world-wide distribution of this fallout material, I would like to discuss for a moment the topic of local fallout.

IV. LOCAL FALLOUT

In a real sense local fallout is of greater significance than world-wide fallout. In the event of a nuclear war, local fallout has the capacity of producing large number of early casualties at distances hundreds of miles away from the point of detonation. In the two weapons utilized in Japan in 1945, there was essentially no local fallout because we used high air bursts and relatively low yields. However, there is no guarantee that any countries would confine themselves to air bursting their weapons in the future because to do this would require a greater expenditure of weapons to knock out the desired targets. For instance, if the Russians wanted to knock out hardened missile sites in the future, they would most likely want to use surface bursts to give the greatest blast damage to the area. Now without doubt, our cities and factories are more susceptible to blast and heat damage than they are to fallout. By this I mean that more casualties would be produced in an all out nuclear war through the use of these properties of nuclear weapons. On the other hand, blast and heat are more localized than the fallout effect. Proper protective steps are possible against local fallout which would reduce the casualties by a large factor. A great deal of information has been made available on protection from fallout.

The OCDM has published a document on the construction of family shelters and there has been a remarkably good study done for the state of New York by the Keith S. McHugh Committee on survival in a nuclear attack. It is an easy matter to show that these protective measures will go a long way in reducing the number of casualties that we might expect from an all out attack. It appears that shelter rather than evacuation is the proper solution.

The problem of local fallout could be of importance in localized atomic attacks such as in a brush fire war where atomic weapons of low yield might be used. Here the commander who might use these weapons, or face them, must be able to calculate the levels of local fallout to expect if he is to make the best use of his terrain or if he is to provide adequate protection to his troops.

Local fallout with its high levels of gamma radiation can produce incapacitating injuries and fatalities within a few days. It does this by giving an acute whole body dose of ionizing radiation which causes changes throughout the body. Now the body can tolerate relatively large acute doses in a localized area without producing immediate deleterious effects. Even a whole body dose of 100 roentgens is easily tolerated. However, a whole body dose of 1000 roentgens given in a short time would probably kill any human exposed to it. Whether or not an individual would receive a lethal dose in any particular situation depends upon many factors, such as his distance from the burst, the period of time he is exposed, and the use he makes of various shielding materials. A great deal of work has been done by the military services to formulate the doctrines of use of weapons and methods of protection of individuals so that casualties will be minimized.

(At this point I would like to make a few remarks off the record.)

V. WORLD-WIDE FALLOUT

I would like now to turn our attention toward world-wide fallout. This is an area that has probably generated as much emotional concern in some circles as any other single activity of the government in recent years. A part of this concern is based upon fear of the unknown. The science fiction treatment of the spread of fallout which was used in the recent theater production of "On the Beach" points up this fact. Actually we know the picture presented in this motion picture is quite wrong. In fact we know more about the world-wide spread of fallout than we do about many other sub-topics of the general fallout problem.

The areas which still contain the greatest uncertainties are those areas dealing with the ultimate biological effects this fallout will have in future years.

A great deal of documentation has been produced both here and abroad which can be used to determine the course taken by bomb debris as it spreads about the world. Measurements have been made by many agencies using many sampling techniques. These have included cloud samples taken by aircraft, rainwater and air samples taken near the surface of the earth, soil samples, food samples, and biological specimens including whole body counting of live people. Each provides an important piece of information. Several years ago it was felt that the greatest uncertainties in determining world-wide fallout were: The amount of material put into the stratosphere, how this material was mixed in the stratosphere, and how it fell out of the stratosphere. There have been a number of programs which have undertaken to determine the amounts in the stratosphere. The AEC has had a balloon program which is now being run by Dr. Machta. My organization has been conducting a high altitude sampling program using aircraft. Various other countries such as the Scandinavians and the British have done similar work. These programs have been complementary in that each has contributed to our knowledge. Over the past few years, we have evolved a rather accurate picture of the manner in which the stratosphere deposits its radioactivity in the lower atmosphere.

I would now like to describe briefly the DASA version of this picture. It was developed from our High Altitude Sampling Program and is in good agreement with the notions that other workers in this field have. When a radioactive cloud is introduced into the tropical stratosphere, it is rapidly elongated in the east-west direction due to shearing action of the east-west winds. At the same time it diffuses northward and southward about one degree of latitude per day. However, there does seem to be a tendency for the cloud to move preferentially toward the hemisphere in which it has been exploded. In the case of our Pacific tests, it appears that two-thirds of the materials were

eventually deposited in the Northern Hemisphere, and the rest in the Southern Hemisphere. Vertical motion of the debris is impeded by the very stable stratification in this region. As this material moves to higher latitudes, it encounters more turbulence especially near the tropopause break with its associated jet streams. The greater majority of this material sifts into the troposphere in the mid-latitude regions where it is rapidly carried to the ground in rainfall. It takes about ten months for half of the material to depart from the stratosphere if it is initially deposited in the lower portion of the tropical stratosphere. For some very high yield weapons, where the clouds go up to 100,000 feet or so, it may take considerably longer to fall out of the stratosphere.

In the case of weapons fired at higher latitudes, which is characteristic of USSR nuclear testing, we find that more of the cloud is injected into the stratosphere, because the tropopause is lower, and that this material comes back out of the stratosphere faster. Recent measurements indicate that half of the material injected into the stratosphere by the USSR in 1958 fell out in about five months.

There seems to be a definite seasonal effect on the rate of drip out from the stratosphere. The spring seasonal increases in activity, noted at ground level, apparently are associated with the increased mixing in the more turbulent, winter time, arctic atmosphere. / troposphere

A rather important feature of world-wide fallout is that there seems to be a close correlation at any one latitude between amounts of rainfall and amounts of fallout. Apparently the major fraction of the radioactive particles is incorporated into raindrops and ~~is~~ removed from the lower atmosphere in rainfall. Residence time in the ~~tropopause~~ is about one month. Specific activities in rainfall will vary considerably from latitude to latitude, however. For instance, the activities found in tropic rains are rather low since most of the activity will have rained out before the air carrying the particles reaches the tropics. This statement of course does not hold in the vicinity of a test shortly after it is held.

Figure 1 shows the uneven manner in which strontium-90 has been distributed in the Northern and Southern Hemispheres. A similar pattern holds for most of the other important fission products. There are obvious peaks in the mid-latitudes, the northern one being more pronounced. The lower value in the equatorial regions shows that little of the material originally placed into the tropical stratosphere falls back across the tropical tropopause. The lower curve on this chart shows our estimate of the total amount of Sr^{90} that has reached the ground in world-wide fallout. The upper curve shows the maximum amount of strontium-90 we may ever expect to find on the ground if there is no more testing. This maximum is expected to occur some time next year. It is apparent that about 90% of the material is down today. This chart accounts for only about two-thirds of all the strontium-90 that has been manufactured during testing. The other one-third has apparently fallen out locally in the testing areas. Unfortunately, we have been unable to make direct measurements of this portion of our production, but this conclusion certainly seems warranted from all the evidence we have at hand.

VI. UPTAKE FROM LOWER ATMOSPHERE

The question now arises, "What happens to this material when it reaches the ground?" At this point our reasonably clear cut notions begin to become somewhat blurred. Since the various fission products which reach the ground have different half-lives and chemical properties, their effect upon man will vary greatly. Dosages to the body can consist of either whole body irradiation or localized irradiation such as to the bone, to the thyroid, or to the skin. Either of these types of dosages may be received from radioactive isotopes residing outside the body or taken into the body.

We are forced to decide which isotopes are of greatest potential hazard and then study each in detail. Strontium-90 and Cesium-137 are the most obvious elements to consider in the case of dosage received from internal sources. They are produced in relatively large abundance, have chemical properties which promote their retention in the body, and have half-lives on the order of 28 years. This latter characteristic is important since a very short half-life would mean that most of the material would decay away before it had a chance to enter the body. Obviously we receive ~~no~~ dose from this material. On the other hand, if the half-life were long the victim would die of other causes before he received much of a dose.

Strontium-90 behaves chemically much like calcium and consequently if taken into the body will be deposited in the bone structure of an individual. Therefore, Strontium-90 is probably the most important single isotope to consider from a health standpoint since its radiations may contribute to the development of bone cancer or leukemia. Cesium-137 and carbon-14 may possibly contribute to the genetic mutation rate in man. Other possibly important materials produced are unfissioned plutonium and iodine-131.

The avenues along which these products can get into the human body are varied. They can fall directly upon vegetables whose leaves can be eaten, or they can be gradually incorporated into plants from the soil through their roots. If these plants are eaten by animals, such as sheep and cattle, we will find these products in our meat and dairy produce.

In this country, milk is the greatest source of calcium in our diet and consequently is the major source of Strontium-90. However, the cow acts as a natural filtration plant in that the strontium to calcium ratio in its milk is only about 15% of the strontium to calcium ratio in its fodder. There is further discrimination in the human body in that the level deposited in bone will be less than that of the diet by a factor which appears to range from two to four.

It appears that the maximum equilibrium bone levels which will be reached in the United States population from material produced by tests to date will average between 5 and 6 micromicrocuries of strontium-90 per gram of calcium. Among Eastern people, where rice is a greater source of calcium, the levels may rise as high as 10 or 12 micromicrocuries of strontium-90 per gram of calcium. The significance of these numbers will be discussed shortly. I might point out that if we were to continue testing at past rates for an indefinite period of time, the levels of strontium-90 in bone would not increase indefinitely. Rather, they would level off at about 8 times their present level, since the amount being made would then equal the amount decaying away.

Much publicity has been given to some of the high levels of strontium-90 in certain foods in the northern part of the U. S. These levels have been generally of rather transient nature, and it is felt that these hot spots in locality and time are not important except to the extent that they add to the overall national average.

VII. EFFECTS OF FALLOUT ON MAN

Although there have been many advances in measurement of the contribution of fallout to the radiation hazard to man, there still remain a number of problems in determining the ultimate effects of such foreign material on humans. Broadly speaking these effects fall into two categories, namely, genetic and somatic. Genetic effects are those effects we may hand down to our offspring through disrupted genes in our reproductive cells. Somatic effects are those effects we may feel in our own body such as diseases or accelerated ageing.

When approaching this problem we are forced to consider past experience in a number of other fields. The direct determination of the ultimate human effects of long term, low level fallout would require many years, since a number of generations would need to be followed. Since we cannot mark time for several human generations, we must use other methods. One approach is to utilize laboratory animals which will produce many generations in a much shorter period. However, this approach presents the problem of interpreting the data in the light of species difference between man and other animals.

Another approach is to relate fallout exposures to other similar human radiation exposure, which occurred long enough ago to allow some analysis of the ultimate results. One such type of exposure which has been occurring since the evolution of man is that of the natural background radiation. This is similar to that fallout radiation which gives whole body radiations, whether from external or internal sources.

The natural background radiation has always existed and actually was greater in the past than it is today. In fact it may be that this radiation was a major contributor to the evolution of the species we find on this earth. This background consists of two parts, that of terrestrial origin and that of extra-terrestrial origin. The latter, known as cosmic radiation, varies with latitude and altitude being greater at higher latitudes and altitudes. The background radiation of terrestrial origin comes from those naturally radioactive elements found in rocks and minerals.

At the present time the chief known sources of natural background radiation on earth consist of:

a. The uranium and thorium ores, including pitchblends, carnalite, and monazite sands. Uranium is also spread widely through rocks and oceans.

b. Potassium-40, a radioactive relative of the stable potassium. Both are normally found in all animal cells and wherever salts are found.

c. Cosmic radiation.

d. Carbon-14, occurring in all organic material as a result of cosmic ray bombardment of atmospheric nitrogen.

In general, the natural background radiation varies roughly between 100 and 150 milliroentgens per year to the world's population.

The variations result mainly from the following factors:

a. Cosmic ray doses are higher with increasing altitude.

b. The component from uranium is lower over the ocean than over the land.

c. Wood used in construction produces less dose than some bricks used in construction.

Whether or not the present background radiation is injurious has not been established. It provides, however, a partial basis for comparison of long term genetic effects from fallout. During the thirty year period starting with 1952, the total dose to human reproductive tissue from both internal and external sources in fallout, which has reached the ground or will reach the ground, will be no more than 0.05 roentgen. This figure has been calculated for the north temperate regions where the fallout is greatest. The natural background, on the other hand, will give a dose of at least 3 roentgens during the same period. In other words, nuclear weapons testing will increase the genetically important background by only 2%.

With regard to localized doses from materials taken into the body, it appears that strontium-90 is the most important isotope to consider. Here we run into difficulty in trying to make a straight comparison between strontium-90 dose to bone and bone marrow and the background radiation dose. It is a relatively easy matter to measure the concentration of strontium-90 in our food and in our bones. However, before trying to relate this information I would like to bring in several other ideas.

I have used the term roentgen rather loosely in describing doses. The roentgen was, until quite recently, the term used in measuring radiation dosage. It is a unit of measurement of the effect of radiation in air. Obviously modification of this unit is needed to relate it to the effect of radiations on materials other than air. The terms rep (roentgen-equivalent-physical), rad, and REM (roentgen-equivalent-man or mannal) have been used as units of absorbed dose. There is no general agreement in the scientific community as to which of these units should be used in describing dose effects relationships.

In attempting to define what ionizing radiation dose-effect relationships provide either no risk or an acceptable risk to humans, the International Commission ~~Committee~~ on Radiation Protection (ICRP) and the National Committee on Radiation Protection and Measurement (NCRP), consisting of experts in the field, have made recommendations as to what levels of exposure they believe are acceptable. These have been termed the maximum permissible concentration (MPC) of radioactive material in air and water and the maximum permissible

dose (MPD) of radiation received from all sources except medical x-rays and background. These are value judgments, made originally for the purpose of determining the level of acceptable risk to those exposed to radiation as a result of their occupation. Since these groups are the most knowledgeable they have been asked for their recommendations of an acceptable non-occupational exposure. With many reservations, the occupational criteria were reduced for application to persons outside of controlled areas, to one-tenth that for radiation workers. Thus, the maximum permissible dose to whole populations from controllable radioactive material should be kept as low as reasonably possible and not to exceed 0.5 radiation units per year (in this case NCRPM used REM as the unit of discussion). This value is considered desirable, since all age groups could be exposed, including children; and consideration must be given to the relative sensitivity of developing organisms in setting the maximum level.

Caution must be used in consideration of the values stated above with respect to individual exposures, since they were established with the whole population in mind. The population level is restricted because of the variance in age of the group, the inability to keep radiation exposure histories on individuals in such a group, and to reduce unforeseen somatic or genetic damages. The committees have stated that an accident or emergency dose of 25 units of radiation (again REMS) occurring only once in the lifetime of a radiation worker, need not be included in the determination of the radiation exposure status of that person. Thus, it is suggested that an individual can tolerate more irradiation than a population.

While these values represent the inclusion of many refinements previously neglected, there remain many uncertainties in the basic biologic data, and exposures should be kept to a minimum. Further, use of these values requires extrapolation in time or in dosage levels, and they cannot be considered final.

Table 1 summarizes the genetic dose and strontium-90 dose we have received from tests to date. Comparison is made between the levels we receive from natural radiation background, the amount we might receive from world-wide fallout in a nuclear war and the amount which the ICRP recommends as a maximum dose. As you can see, the contribution from fallout to date is quite low.

VIII. CONCLUSION

To conclude I would like to summarize a few of the major points we have made.

We know a great deal about the mechanisms of formation of the radionuclides we find in fallout and we know a great deal about how this material is spread around. While there are gaps in our knowledge on these points we feel that we can make reasonably accurate predictions in this area. Surprisingly enough the local fallout picture is more obscure than the world-wide fallout picture. Continuing work is being done to throw more light on both. We know that in the event of nuclear war, local fallout would be a great danger to our populace. In the case of an all out nuclear exchange, our people would not be wiped out; however, we could expect very large numbers of casulties in the countries under attack. These could be materially reduced if proper shelter is utilized.

With regard to effects of radiation on man, we know more about what constitutes a casualty producing lethal dose than we do about the chronic effects of low level radiation. There has been much surmise based on few facts, and it is difficult to say what valid conclusions can be drawn from the scanty evidence available.

The ICRP and NCRP have recommended maximum permissible levels of radiation for the whole population, which levels are closely related to the natural background dose we cannot avoid. It appears that the nuclear testing to date has not raised the average dosage levels by more than about 10% of this background and this will diminish in time to less than 1%.

TABLE I RADIATION DOSAGE IN THE UNITED STATES

	Natural Background	Tests to Date	Possible War	ICRP MPD
GENETIC (whole body dose 30 yrs)	3 rem	0.05 rem	0.9 rem	15 rem
SOMATIC (Sr-90 dose to bone 1 yr)	100 mr	6 mr	120 mr	350 mr

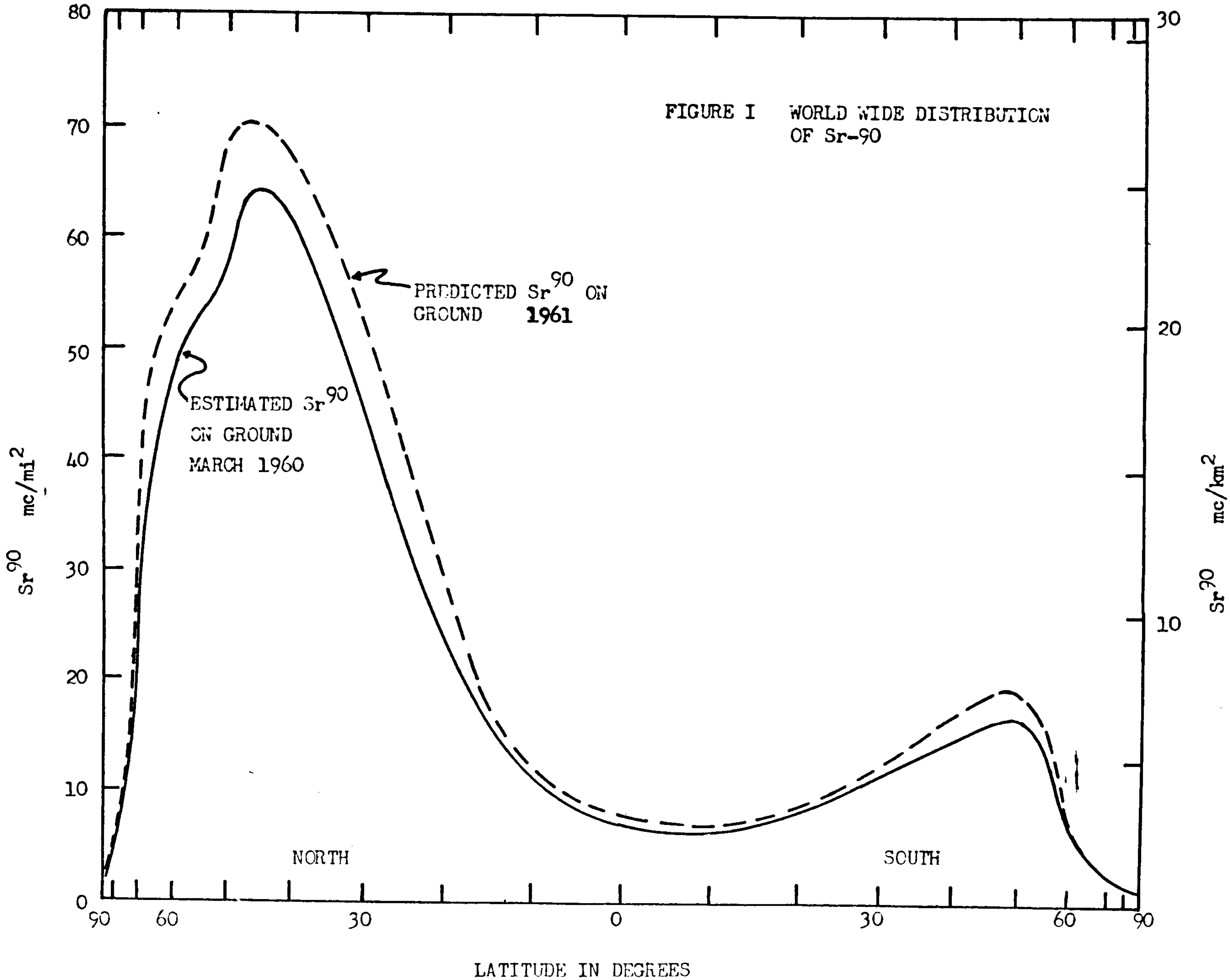

FIGURE I WORLD WIDE DISTRIBUTION OF Sr-90

G L O S S A R Y

background:--A term used to describe the natural radiation of the earth and its atmosphere. It consists of cosmic radiation and radioactivity in the earth, air, and water.

beta particle:--A high-speed electron emitted by nuclei which are neutron-rich. As electrons are very light, even with only a few hundred kilovolts of energy they move at speeds near that of light, 3×10^{10} cm/sec. They therefore ionize slightly in comparison to protons or alpha particles of the same energy.

carbon-14:--A radioactive isotope of carbon formed in the atmosphere by neutron bombardment of nitrogen. Carbon-14 emits a beta particle of maximum energy 0.16 Mev and has a half-life of 5,600 years.

cesium-137:--A radioactive isotope of cesium, the element of atomic number 55. It emits a .66 Mev gamma ray and a beta particle, thus decaying to barium-137, which also emits a .66 Mev gamma. Cesium-137 has a half-life of 30 years.

clean bomb:--A predominantly fusion weapon.

cosmic rays:--High-energy particles which bombard the earth from outer space. The particles hitting the top of the atmosphere are mostly protons, but in the collisions with air nuclei, other forms of radiation are produced, with a wide range of energies and penetrating power.

dose:--The dose or exposure is the energy transmitted to the irradiated material. See rad, rem, rep, roentgen.

fission:--The nuclear process in which a nucleus splits in two and releases energy. It is a process characteristic of the heavy elements, uranium, plutonium, thorium, etc. This process provides the energy for the atomic bomb and nuclear reactors.

fusion:--The nuclear process in which two light nuclei join together to form a heavier one. It occurs most readily with hydrogen and its isotopes. This process provides the energy for the hydrogen bomb.

gamma ray:--A penetrating radiation emitted by a radioactive nucleus. It is of the same general nature as X-rays and ordinary light, though more energetic. Its energy is usually a few Mev. Gamma rays of this energy can penetrate considerable thicknesses of matter.

half-life:--The physical half-life of a radioactive nucleus is the time during which it has a 50:50 chance of disintegrating. Given a collection of nuclei of the same species, the half-life is the time during which half of them will undergo disintegration and change into the daughter product.

iodine-131:--A radioactive isotope of iodine the element of atomic number 53. It emits several gammas (.1, .3, .4, and .6 Mev) and has a half-life of 8 days.

induced activity:--Activity caused in an element by impinging radioactive particles (neutrons).

ionizing radiation:--Radiation which causes normally stable elements to ionize.

isotope:--Isotopes are nuclei having the same number of protons i.e., the same atomic number, but differing in the number of neutrons, i.e., having different atomic weights. Isotopes of an element are chemically identical but possess quite dissimilar nuclear properties.

kiloton:--A measure of nuclear weapon energy. A one-kiloton weapon releases the same amount of energy as would 1,000 tons of TNT.

local fallout:--That fallout which is on the surface within several miles to several hundred miles of burst point.

mega:--A prefix meaning million (10^6); thus a megacurie is a million curies.

micromicro:--A prefix meaning a millionth of a millionth (10^{-12}).

mutation:--A transformation of the gene which alters its heritable character. Mutations may be induced by radiation.

neutron:--Along with the proton a basic building block of the nucleus. The neutron has about the same mass as the proton but is uncharged. Free neutrons decay to protons plus beta particles with a half-life of 12 minutes.

nuclides:--Stable atoms or ones that have reasonable half-lives.

plutonium:--One of the very heavy elements, atomic number 94. Plutonium 239 is used as a fissionable material in nuclear weapons.

rad:--A unit of radiation exposure, or absorbed dose. It is a measure of the energy imparted to a piece of irradiated material and is defined as 100 ergs per gram. It is the unit recommended by the International Commission on Radiological Units.

rem (roentgen equivalent man):--The most common unit of radiation exposure, or dose. It is that quantity of ionizing radiation which produces, when absorbed by man, an effect equivalent to the absorption of one roentgen of X-rays or gamma radiation. The dose in rem is obtained by multiplying the dose in rads by the appropriate RBE.

rep (roentgen equivalent physical):--A measure of absorbed radiation. The amount of ionizing radiation which will result in the absorption of 83 ergs in one gram of tissue. (Some authorities use 93 ergs).

roentgen:--The standard measure of X-ray exposure, usually abbreviated r. It is that exposure which in 0.00293 gm. of air will produce ions carrying a total of one electrostatic unit of charge, i.e., about 10^9 electrons and a like number of positive ions. This energy absorption amounts to about 88 ergs per gram.

somatic:--Pertaining to all tissues other than the reproductive cells. Somatic effects are limited to the irradiated organizm itself and do not carry over to succeeding generations.

stratosphere:--The portion of the atmosphere above the troposphere. In this region the temperature changes but little with altitude, and clouds of water vapor seldom occurs.

strontium:--The element of atomic number 38. Strontium-90, one of its radioactive isotopes, emits a 0.61 Mev beta particle and has a half-life of 28 years.

tropopause:--The imaginary boundary between the stratosphere and the troposphere In middle latitudes its height is about 25,000 to 35,000 feet; in the tropic it is 50,000 to 60,000 feet above the earth's surface. The height depends somewhat on the season.

troposphere:--The lower part of the earth's atmosphere, containing our weather--coulds, rain, mist, etc.

world-wide fallout:--That debris which remains air borne long enough to be deposited around the world (at latitudes in the vicinity of the burst.)